EFFECTIVE BEHAVIOR, MICROSTRUCTURE EVOLUTION AND MACROSCOPIC INSTABILITIES IN REINFORCED ELASTOMERS

O. Lopez-Pamies [1,2], P. Ponte Castañeda[1,2]

[1] LMS, Département de Mécanique
Ecole Polytechnique
91128 Palaiseau, France

[2] Department of Mechanical Engineering and Applied Mechanics,
University of Pennsylvania
Philadelphia, PA 19104-6315, U.S.A.
olp@seas.upenn.edu

This paper is concerned with a general homogenization framework [1] for determining the overall behavior, the evolution of the underlying microstructure, and the possible onset of macroscopic instabilities in fiber-reinforced elastomers subjected to finite deformations. The main concept behind the method is the introduction of an optimally selected nonlinear comparison composite, which can then be used to convert standard linear homogenization estimates into new estimates for the nonlinear hyperelastic composite. We make use of this framework to generate specific results for general plane-strain loading of elastomers reinforced with aligned cylindrical fibers [2]. For the special case of rigid fibers and incompressible behavior for the matrix phase, *closed-form, analytical* results are obtained. The results suggest that the evolution of the microstructure has a dramatic effect on the effective response of the composite. Furthermore, in spite of the fact that both the matrix and the fibers are assumed to be strongly elliptic, the homogenized behavior is found to lose strong ellipticity at sufficiently large deformations, corresponding to the possible development of macroscopic instabilities [3]. The connection between the evolution of the microstructure and these macroscopic instabilities is put into evidence. In particular, when the reinforced elastomers are loaded in compression along the long, in-plane axis of the fibers, a certain type of "flopping" instability is detected, corresponding to the composite becoming infinitesimally soft to rotation of the fibers.

References

[1] O. Lopez-Pamies and P. Ponte Castañeda. On the overall behavior, microstructure evolution and macroscopic stability in reinforced rubbers at large deformations: I Theory. *Journal of the Mechanics and Physics of Solids* (2006): in press.

[2] O. Lopez-Pamies and P. Ponte Castañeda. On the overall behavior, microstructure evolution and macroscopic stability in reinforced rubbers at large deformations: II Application to cylindrical fibers. *Journal of the Mechanics and Physics of Solids* (2006): in press.

[3] Geymonat, G., Müller, S., Triantafyllidis, N. Homogenization of nonlinearly elastic materials, microscopic bifurcation and macroscopic loss of rank-one convexity. *Arch. Rat. Mech. Anal.* **122** (1993): 231–290.

Keywords: composite materials, microstructure evolution, stability